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STATES OF AWARENESS I: SUBLIMINAL PERCEPTION RELATIONSHIP TO SITUATIONAL AWARENESS

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This report has been reviewed and is approved for publication.

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On the face of it, subliminal perception violates common sense. How can a stimulus for which you have no knowledge make any difference? In its simplest terms, the answer is as follows: 1) when you have a known stimulus at a known intensity; 2) which is at or below the level of conscious awareness; and 3) behavior on a concurrent or subsequent task is modified; then 4) you have a subliminal perception. This report reviews and integrates the literature on subliminal perception. We review the history (early research was weak) and theoretical roots. Then we examine in detail the five prominent methodologies: signal detection, dual channel, masking, lexical decision, and neurophysiologic, the latter very briefly. The main part of the review addresses two major areas: Subthreshold information acquisition and subconscious information processing. Current criticisms are examined. Operational relevance is discussed. The significance of subliminal perception for operational applications is that it provides a methodological basis for one kind of training to enhance situational awareness.

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FOREWORD

This review of subliminal perception is part of a detailed analysis and integration into two broad subjects: 1) human performance, and 2) states of awareness. The objective is to develop tools to improve fighter pilot performance through the enhancement of situational awareness: Our exhaustive review spanned 1983-1987 and was followed by the development of a prototype situational awareness training system, delivered to the Armstrong Laboratory in 1991. Subliminal perception is one of a subset of reviews on states of awareness which includes the following reviews:

- Subliminal perception
- Subliminal perception and psychodynamic issues
- Neurophysiologic basis for subliminal perception
- Extrasensory perception
- Cognitive regulatory skills
- Information processing capabilities
- Components of situational awareness
- The case for parallel information processing systems
- Enhancement of situational awareness

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STATES OF AWARENESS I: SUBLIMINAL PERCEPTION RELATIONSHIP TO SITUATIONAL AWARENESS

INTRODUCTION

Our search for a conceptual foundation of situational awareness led us to examine many areas of the behavioral sciences; subliminal perception was one. What follows is a comprehensive review of the literature on subliminal perception, with periodic references to its relationship to situational awareness.

The concept of subliminal perception concerns the notion that individuals can acquire, analyze, process, and be affected by sensory stimuli below the level of conscious awareness. This means that an individual need not consciously experience external stimuli for attendant sensory information to register and influence perception, cognition, neurophysiology, and behavior. The concept implicit in such a viewpoint is one of a parallel, preconscious information acquisition and processing system. This idea contrasts with traditional thinking which emphasizes conscious, sequential processes and phenomenological organization in the acquisition and processing of information.

The possibility that information can be acquired and processed subliminally and subsequently influence behavior is one of profound significance with far-reaching implications for human performance. Once behavioral scientists understand the mechanisms of subliminal perception, they can develop and exploit subthreshold information acquisition and processing capabilities to substantively enhance human performance and situational awareness.

The focus of this review will be on potential applications in fighter pilot performance. Fighter-attack pilots are crucially dependent on finely honed perceptual-cognitive skills and keen situational awareness. A highly developed subliminal perception capability offers the potential to dramatically increase human capacities to detect, acquire, and process performance-critical information. The resultant increase in perceptual-cognitive effectiveness and heightened situational awareness can provide a decisive combat performance edge for tactical aircrews.

Initially, we will examine relevant background issues that relate to subliminal perception, including its significance, history, and theoretical roots. We will then describe selected methodologies employed in subliminal perception and subthreshold information processing research. In all, we will review five prominent methodological approaches: signal detection, dual channel, masking, lexical decision, and neurophysiological approaches. Next, the main part of this review is devoted to an assessment of the empirical evidence for subliminal perception and criticisms of that evidence. This assessment is organized under two major sections: Subthreshold Information Acquisition and Subconscious Information Processing. The final topic presents the operational relevance of subliminal perception.

BACKGROUND

Historical Synopsis

The conceptual origins of subliminal perception have been traced as far back as the writings of Aristotle. It has been noted that Aristotle referred to perceptual thresholds and signal-to-noise ratios as early as about 450 B.C. (23). Many centuries later, in the late 1600s, Leibnitz wrote about subconscious perception and perceptions that become known only by consequences. In the early 1900s, Titchener observed that conscious processes often result from nonconscious processes.

The period between 1860 and 1960 brought about an increased interest in subliminal perception and related research. In the late 1950s, McConnell, Cutler, and McNeil (76) sought to review historical evidence for subliminal perception and to ascertain whether it is a credible concept. Their extensive review embraced relevant research dating from 1863 to about 1957. Although there were many experimental shortcomings and methodological weaknesses identified, McConnell et al. concluded that the phenomenon of subliminal perception did occur under certain conditions.

During the early 1950s, subliminal perception research was mostly concentrated in the area of perceptual defense (9,23). The emphasis shifted in the 1960s toward an increasing concern for discovering the personality correlates of subliminal sensitivity (9). Of special interest was the early work that assessed subliminal receptivity in terms of neurophysiological response (e.g., GSR, EEG) to subthreshold emotional information and an accompanying increase in the recognition threshold for emotion-producing stimuli.

By the 1960s, inquiry and investigation into subliminal perception fell into disrepute and evidenced a dramatic decline in credibility and respectability. During the last 15 years, this trend has reversed. Increased theoretical effort and more rigorous empirical research have produced a greater willingness to consider subliminal perception as a legitimate area of scientific endeavor.

Theoretical Orientation

The study of subliminal perception was initially spawned by merging two fundamental psychological premises: (a) that mental events are measurable and (b) that behavior can be determined by stimuli outside the limits of conscious awareness. The former premise was given impetus by Weber-Fechner psychophysics and the latter premise by Freud's psychoanalytic theory.

Early theory concerned with subliminal perception stressed the Freudian link, with considerable emphasis on psychoanalytic concepts. This line of thought postulates that at some level below conscious awareness, subliminal stimulation arouses subconscious associational networks (122,123).

As the theoretical and conceptual work continued to evolve, more precise definitions of subliminal perception were fashioned. Dixon (23) proposed that in order for stimuli to be considered subliminal, they must meet three standards:

- The stimulus energy levels must be directed below an appropriate, predetermined threshold.

- The individual must not be consciously aware of the stimulus content (either during or after stimulus presentation).

- The stimulus must result in contingent responses that are qualitatively different from those elicited by the same stimulus when it is presented above the awareness threshold (establishes subliminal perception as a distinct and separate phenomenon).

Later, Dixon (24) defined subliminal perception more succinctly as a situation in which a definable physical stimulus evokes a measurable behavioral or neurophysiological response without conscious awareness. In this case, subliminal perception involves a stimulus that is insufficient to activate cerebral processes responsible for the conscious awareness of incoming sensory stimuli, yet it is sufficient to produce a neurophysiological or behavioral reaction. The emphasis is on physically present sensory stimuli that are below the level of conscious awareness (96,97).

With respect to the origin and the biological necessity for subliminal processes, Dixon (23) suggested that, as the potential for conscious experience developed through the evolutional process, a control mechanism became necessary to avoid perceptual-cognitive overload. It would appear that control could be exercised either by a substantial reduction of sensory inflow or by selectivity over information permitted to reach consciousness. Clearly, a dramatic restriction of sensory inflow would mitigate against survival. Thus, a system that exercises selective control over information allowed to reach conscious awareness seems to be a more plausible alternative.

The evolution of perceptual-cognitive processes refined the role of conscious awareness in humans to produce the need-oriented consciousness that characterizes the modern personality. Dixon (25) has described five major features of human perceptual-cognitive systems that reflect both conscious and subconscious information acquisition and processing capabilities.

- A large, continuously operating information capability for surveillance.

- An enormous information storage capacity organized according to personal needs (e.g., arrays of drive schemata).

- A hierarchy of information acquisition and processing phases that concentrate on comparative analysis and classification of information structure and meaning against appropriate memory stores.

- A system of regulatory mechanisms whereby need or activational states can exercise control over perceptual, memoric, and decision processes.

- An action or decision execution system wherein the results of sensory-perceptual, memoric-cognitive, and need-motivational states interaction can be translated into plans and responses.

The foregoing represents the requirements for both conscious and subconscious access to and control over sensory information. These five features also provide a theoretical rationale for interactive dual systems of information acquisition and processing that more adequately explains the formidable human perceptual and cognitive capabilities. Since conscious awareness typically focuses on what is important, novel, and of pressing relevance, four theoretical propositions were formulated for human perceptual-cognitive performance (25).

- Conscious awareness per se implies that there are criteria for the conscious representation of stimuli which must be applied at some preconscious phase of information acquisition and processing.

- In order to efficiently select important information for entry into consciousness, preconscious processing phases must provide for both structural and semantic analysis of sensory inflow and interaction with long-term memory.

- Conscious channel capacity relative to the capacity for sensory acquisition is limited; therefore, a large proportion of sensory input information never attains conscious awareness, notwithstanding its complete subconscious processing up to and including semantic analysis.

- Despite not achieving conscious awareness, subliminal information can profoundly influence perception, memory, cognition, neurophysiological activity, behavior, and consciousness per se.

As empirical research began to build a scientific foundation for the concept of subliminal perception, its widely proclaimed theoretical disparity with the traditional behavioral sciences diminished. For the most part, early research findings and related constructs were surprisingly compatible with prominent psychological theory and principles (9). We will address in detail the growing body of empirical evidence on subliminal perception and solid linkages that have been established with a number of prominent theories and accepted principles in the behavioral sciences. For the present, however, a few examples will suffice.

Helson's (55) adaptation-level theory, for example, provides for an integration of multisource inputs from the external environment, memory, and internal states to produce a current set of norms or standards which become an individual's benchmarks for assessing subsequent stimuli. The combined effects of subliminal and supraliminal sensory stimuli are consistent with Helson's hypothesis that adaptation level is determined by all stimuli in an individual's attention field plus background stimuli and relevant residuals from past experience. Adaptation level theory is usually applied to supraliminal stimulation,

but the concept of subliminal perception can be easily accommodated within the Helson theory.

Fechner's law can be interpreted from the perspective that adaptation level is the origin or baseline for specific psycho-physical functions. Since psychophysical principles are concerned with combining background and residual stimuli with ongoing or focal stimuli, the inclusion of subliminal stimuli within both a psychophysical and an adaptation framework is entirely plausible.

Another theoretical linkage to subliminal perception reaches back to Gestalt psychology. A primary function of Gestalt principles is to explain the process of analyzing the stimulus array into basic elements and the consequent organization of the stimulus field. Anderson (1) has summarized five emergent manifestations of Gestalt principles that are important to the perceptual integration and organization of sensory information.

- Proximity -- the tendency to organize elements that are close together into a single perceptual unit.

- Similarity -- the tendency to group items together that look alike.

- Continuation -- the tendency to perceive lines that are flowing in the same direction as connected.

- Closure -- the tendency to create pleasing forms from suggestive but incomplete shapes.

- Symmetry -- the tendency to see symmetrical shapes in patterns.

It seems that human perceptual processes have an inherent tendency to impart structure and organization where there is lack of precedence or ambiguity. Gestalt principles appear to assert primacy in the absence of overriding structural and organizational factors such as knowledge, familiarity, experience, context, and set. In other words, stimulus patterns are most likely to be organized according to Gestalt principles when they are unfamiliar or lack meaning.

The relationship between subliminal perception and Gestalt principles was recognized many years ago. It was noted that the Gestalt principles of organization appear to be applied to sensory inflow subconsciously and at a point subsequent to interaction with the long-term memory system (23,38,89). Since Gestalt principles seem to be applied when stimulus patterns lack meaning, it is also possible that subthreshold information influences the organization of the percept.

Another theoretical reference to subliminal perception is the concept of penumbra (139). This notion ascribes a figurative penumbra or shadow to perception. In this respect, Weintraub and Walker discuss

a perception and its penumbra (perception/penumbra = perception/subliminal aura = suprathreshold/subthreshold information). In other words, perception and its penumbra or shadow are figurative references to supraliminal perception and its subthreshold counterpart now formally referred to as subliminal perception.

It is likely that what Weintraub and Walker have in mind is subliminal perception. They describe penumbra as perception in the absence of a conscious sensory gradient (the stimulus is too weak for conscious awareness). They also identify penumbra with situations in which the stimuli are suprathreshold but not attended to (conditions in which the afferent inflow is structured such to obscure its presence from conscious awareness).

In summarizing the theoretical orientation just described, it is important to emphasize that the theoretical cornerstone of subliminal perception is the premise that an individual's capacity to acquire and process information is not dependent on, nor does it necessarily involve, conscious awareness of the information (25). From this perspective, consciousness is rather loosely connected to a formidable information acquisition and processing system that has both conscious and subconscious processes. Accordingly, an individual remains consciously oblivious to a sizeable amount of sensory inflow and consequent neurophysiological and behavioral activity. In this regard, particular attention should be given to the evidence to be described later for dual systems that permit both supraliminal and subliminal information acquisition and processing, frequently simultaneously.

From his review of early subliminal perception research, Bevan (9) reached three principal conclusions that are still valid today. These three conclusions have served as a point of departure for our review of the empirical research accomplished during the last two decades.

- Subtle stimulation below the threshold of conscious awareness can influence a variety of response systems.

- The effects of subliminal perception are real but can be difficult to reliably produce.

- Subliminal stimulation produces three major types of responses: (a) responses that are essentially the same as those resulting from supraliminal stimulation, (b) responses that delay or nullify expected reactions to supraliminal stimulation, and (c) responses that modify or change the consequences of supraliminal stimulation.

RESEARCH METHODOLOGY

It is appropriate to consider the various methodologies employed in the subliminal perception and subconscious processing research prior to proceeding with the review and assessment of empirical work. An understanding of these methodologies will make the review more meaningful and examples of their use in research will make their respective characteristics more explicit.

In general, the acquisition and processing of subliminal information can be demonstrated in two ways. First, the ratio between signal and noise can be such as to preclude conscious awareness. Second, a lack of conscious awareness can be produced by controlling or modulating a number of individual variables, including arousal, attention, neurophysiological activation, processing level or stage, and the extent of involvement of the various sensory modalities and channels. Both of these general approaches and their manifold variants have been employed in a variety of experiments.

In most of the experimental paradigms dealing with subliminal perception and subconscious information acquisition and processing, the categorization of independent and dependent variables is reasonably straightforward. Dependent variables usually involve some sort of perceptual-cognitive response such as detection, recognition, or identification of an external target or object; or judgments or decisions regarding specified aspects of the stimulus field's sensory inflow, imagery content, or dream composition. The independent variable is typically a stimulus, stimulus array, or some other specified information that does not reach conscious awareness.

Behavioral scientists have utilized a number of different methodological approaches or investigative paradigms to study subliminal perception. For ease of reference, these commonly used paradigms have been categorized into five general methodologies: signal detection approaches, dual channel approaches, masking approaches, lexical decision approaches, and neurophysiological approaches. Although each methodological category represents a number of paradigmatic variants, the essential characteristics of the variant paradigms belonging to each methodological category are essentially the same. A brief review of the salient features of each general methodology follows. Subsequent to the review of general methodologies, a number of related procedural matters are discussed.

Signal Detection Method

Signal detection methodology is grounded on signal detection theory (128,129). It has the capacity to segregate sensory sensitivity from response-mediated effects. Accordingly, the signal detection approach is superior to psychophysical paradigms for investigating subthreshold sensory inflow and subconscious processing because psychophysical approaches are derived from threshold models which confound sensory sensitivity and response criteria. As Stevens (127) emphasized years ago, threshold is not invariant with time, but instead shifts constantly as a function of both internal state factors and external situational factors.

The signal detection methodology partitions responses to external stimuli into: (a) factors that influence sensory acuity or sensitivity and (b) factors associated with deciding on a response to what is sensed. The signal detection approach is useful in studying a wide variety of issues pertaining to subliminal perception. It can be easily

employed in conjunction with other methodologies, including all of the other investigatory paradigms discussed in this section. Signal detection paradigms are especially appropriate for investigating the extent to which sensory sensitivity can be influenced by sensory inflow that is below the threshold of conscious awareness. Microgenesis studies focusing on the growth of percepts as a function of gradually increasing stimulus energy are also well suited for signal detection paradigms.

The issue of subliminality or extent to which subliminal stimuli are below the threshold of consciousness is handled quite well by the signal detection approach. A subliminal stimulus is defined as a signal-to-noise ratio that prevents the stimulus from producing any conscious effect at the time of presentation. Provided the signal-to-noise ratio meets this requirement, the situational conditions are not important. For example, the noise level can be high, as in masking and metacontrast methodologies, or low, as in the determination of psychophysical threshold. Subliminality, then, is directly related to noise level in the signal detection paradigm and can vary greatly from one noise condition to another.

Signal detection paradigms are also amenable to examining a variety of variables of special interest to the study of subliminal perception and subconscious information acquisition and processing. These variables include the singular and interactive effects of signal strength (intensity and duration), external noise, internal noise, signal meaning (which includes emotional meaning, personal significance, and task/situational importance), significance and focus of conscious attention, as well as other relevant internal and external factors. As will become evident later, the signal detection approach is well suited for examining a central construct of subthreshold information processing: the matter of subconscious analysis of meaning. In this regard, the sensory sensitivity (d') component of the signal detection approach appears to be finely tuned to the emotional meaning of sensory inflow and related derivatives of personal significances and task/situational importance.

Dual Channel Approaches

Dual channel methodologies explore the influence effected by subthreshold stimulation in one sensory channel or modality on the suprathreshold information being processed by another sensory channel or modality. These approaches include experimental paradigms that employ methods such as binocular rivalry, dichoptic viewing, and dichotic listening. In general, these paradigms present subliminal information to a sensory channel not currently mediating conscious perception. Examples include the presentation of subthreshold information to the suppressed eye during binocular rivalry; and subliminal auditory input to one ear while the other ear is engaged in a verbal shadowing task.

The dichoptic viewing paradigm is a popular dual channel approach that has a number of methodological variants. An early version of the dichoptic viewing paradigm measured variations in the sensitivity of one

eye as a function of subliminal stimuli presented to the other eye (21,23,26,59). In this approach, subthreshold stimuli are presented to one eye while the other eye provides a metric of threshold change to a spot of light. Subliminality of the subthreshold stimulus is attained by varying intensity rather than duration.

Another variant of the dichoptic viewing methodology is the binocular rivalry paradigm mentioned earlier. This paradigm has been proven quite useful in subliminal perception research (25,90,118,136,137,138). The binocular rivalry method provides a reasonably precise measure of sensory sensitivity; at the same time, it virtually eliminates the influence of response effects.

In the binocular rivalry paradigm, a stimulus of specified intensity is presented to one eye and another stimulus of greater intensity is presented to the other eye. Either stimulus is clearly visible when it is presented to each eye separately. However, if a stimulus of higher intensity is presented to one eye concurrently with a lower intensity stimulus to the other eye, the higher intensity stimulus will totally suppress phenomenological representation of the lower intensity stimulus. Thus, a stimulus which under normal conditions would be consciously perceived is suppressed by contiguous stimulation of the other eye with a higher intensity or brighter stimulus. This suppression does not occur if both stimuli are presented to the same eye.

In binocular rivalry paradigms, conditions are created in which information presented to only one of two eyes attains conscious awareness. However, sensory inflow from the dominant eye (conscious processing) and from the suppressed eye (subconscious processing) are received and processed. Any variation or change in the stimulus being received by the nondominant eye causes a rivalry reaction that reverses the functional responsibility for acquiring and processing suprathreshold versus subthreshold information.

The dichotic listening paradigm is another dual channel methodology (19,20,25,58,67,68,71). This approach requires the individual to shadow or repeat information presented to one ear at a rate that does not permit a shift in attention without losing part of the attended message (e.g., about one word every 2/3 seconds). Information is presented concurrently to the unattended ear to determine whether the subliminal input has any effect on the supraliminal information received by the attended ear.

Masking Paradigm

Masking paradigms involve the application of either energy masks or pattern masks immediately following stimulus onset. Such masking terminates the orderly information acquisition and processing sequence. By varying the time of mask onset with respect to a particular stimulus, the elements and events of perceptual-cognitive processing can be examined in detail and the influence of the masked stimulus on the processing of suprathreshold stimuli can be determined. In essence, masking enables the investigator to study perceptual-cognitive processes

through assessing the influence of incompletely processed subliminal sensory on supraliminal sensory inflow.

The masking approach can yield valuable insights regarding the time course and structure of perceptual-cognitive processing. Conscious awareness of the masked stimulus is precluded by the brevity of the time interval between the stimulus to be masked and the onset of the mask. The duration of the brief time period between onset of the stimulus to be masked and the mask is known as stimulus onset asynchrony (SOA). By varying the SOA, it is possible to sequentially evaluate subconscious acquisition and processing using a millisecond time base and to assess the resultant incremental influences in relation to the processing of subsequent suprathreshold sensory inflow.

Some of the earlier applications of the masking methodology were identified as metacontrast paradigms. In fact, a selection test based on the metacontrast technique was developed to screen pilot applicants for the Swedish and Norwegian air forces (25,65,117). Metacontrast methodology also has been used in clinical situations to investigate the relationships between psychological defenses, anxiety, and psychopathology (112,113,114).

More recently, masking paradigms have been increasingly utilized in studies of subliminal perception and subconscious processing. With increased use of the masking methodology, the need to distinguish between energy and pattern masking became apparent. While both energy and pattern masking preclude stimuli from conscious awareness, they operate differently and have disparate consequences (131).

Energy masking, also termed peripheral masking, constitutes an energy override of sensory inflow which eradicates the information being acquired or processed. The previous section on dual channel processing provides some insight to energy masking. Pattern masking, also known as central masking, involves the use of pattern or contour information to degrade stimulus quality before it is consciously perceived. In the case of energy or peripheral masking, virtually no information about the stimulus is acquired or processed. Conversely, central or pattern masking permits the subconscious acquisition and processing of certain semantic and physical features, even though the stimulus is well outside the limits of conscious awareness (73).

The operational distinctions between peripheral (energy) and central masking have been succinctly described by Marcel (73). He defines peripheral masking as an energy function that is effectively achieved with either a blank field, noise field, or contoured field, provided the energy and time relations between the stimulus and mask are appropriate. Peripheral masking can be obtained through both forward and backward masking, but cannot be achieved dichoptically (only monoptically). Central masking, on the other hand, is effectively attained only with a contour pattern and backward masking. Additionally, central masking is possible both monoptically and dichoptically and is implemented using an onset-onset function.

One methodological approach that utilizes energy (peripheral) and pattern (central) masking as well as a no-mask comparative condition has been employed by Marcel (73). This approach uses subthreshold priming stimuli and suprathreshold target stimuli, separated by the three different masking conditions. In the energy masking condition, noise masks the priming stimuli monoptically (dominant eye); for the pattern masking condition, an appropriate pattern contour masks the priming stimuli dichoptically. Numerous SOAs were used for both the energy and pattern masking conditions. The no-mask condition involved a single, standard no-mask interval between the priming and target stimuli (e.g., about 500 msec).

Experimental paradigms such as the type used by Marcel have considerable utility in delineating the respective subconscious and conscious perceptual-cognitive events that are involved in information acquisition and processing. In recent years, the masking approach has been used in conjunction with lexical (broadly defined as the meaning of words presented as stimuli) decision tasks to produce an effective combined methodology for examining subliminal perception and related subconscious processes. The methodology used in the joint masking-lexical decision studies is addressed next.

Lexical Decision Model

The lexical decision methodology typically involves brief subthreshold tachistoscopic presentation of a priming cue intended to bias a subsequent suprathreshold signal. The priming cue is followed immediately by a pattern mask to be certain that the cue cannot be consciously perceived. Use of the lexical decision approach permits the identification of time-course differences related to perpetual-cognitive processing events.

Experimental paradigms using lexical decision methodologies often combine pattern masking with a range of stimulus-onset asynchronies (SOAs) to determine the salient characteristics of subconscious information acquisition and processing (5,25,41,75). As indicated earlier, SOA refers to the length of the brief time period between onset of the priming cue (or target stimulus if there is no priming cue) and onset of the pattern mask. The range of SOAs employed varies among experiments, but nearly always involves SOAs too brief for conscious awareness of the priming cue. The lexical decision task in combination with a variety of priming cues and SOAs enable the investigator to properly assess the temporal course of subconscious analysis as well as the influence of subthreshold priming cues on the speed and accuracy of target recognition and identification.

Neurophysiological Approach

Experimental paradigms with provisions for neurophysiological measures certainly aren't peculiar to subliminal perception and subconscious processing research. They are briefly mentioned here to acknowledge the concern among some investigators for understanding the electrophysiological and autonomic activity that is evoked by subliminal

information acquisition and processing. Of the many neurophysiological measures that have been employed in subliminal perception research, electroencephalogram (EEG) and electrodermal or galvanic skin response (GSR) assessments have been the most prominent. There will be further discussion of this methodology as part of the assessment of empirical research later in this review.

Procedural Issues

Research concerned with subliminal perception and subconscious information acquisition and processing requires special procedural and methodological considerations. It is sufficient here to note some of the more important of these considerations as background for the review and assessment of research to be reported later.

The main criterion in generating subliminal stimuli is to individually tailor the energy level (intensity) and duration to fall between the neurophysiological threshold and the threshold of conscious awareness (23,25). It is essential to take special care that sensory stimulation is placed within the desired subthreshold parameters for each experimental subject. Subliminal stimulation must not only be at subthreshold for conscious awareness, but it also must be sufficiently strong to neurophysiologically activate the receptors and engage the electrophysiological processing mechanisms.

With respect to the subliminality of the sensory inflow, Dixon (23) has observed that the closer a subliminal stimulus is to the threshold of conscious awareness, the less potential it has for influence. Other early investigators have also found that subliminal effects were greater when substantially below, rather than slightly below, threshold (34,89,115,116,123,149). Consistent with these findings, Fiss (39) noted that subthreshold stimuli are most efficiently acquired when they circumvent critical evaluation and reality testing. In this regard, Dixon (25) suggests that subliminal stimulation is more effective when it is well below the threshold of conscious awareness for two reasons: (a) because conscious perception of fleeting structure may initially have an inhibitory effect and (b) because changes occur in the activation potential of the nonspecific extralemniscal system as stimuli approach the threshold of conscious awareness.

Several methodological features that militate against the acquisition and processing of subliminal information have been identified by Dixon (25). Specifically, Dixon's admonition applies to any characteristic inherent in the experimental paradigm that interferes with the peripheral receptor in question or directs attention away from the sensory modality intended to acquire and process the subliminal information. To these caveats might be added circumstances that establish motivational set, expectancies, or response tendencies which focus conscious attention or diminish perceptual receptivity. Arousal or activation levels that generate excessive internal noise, heighten self-concern, or lower sensitivity to the external stimulus field would all seem to diminish subliminal perception.

Several procedural peculiarities are applicable to subliminal perception research. They are briefly mentioned with appropriate reference citations in the event the reader or investigator needs to examine or use the special procedural requirements. Some of the more important special procedural requirements include: (a) stimulus intensity and duration parameters to ensure subliminality (2,23,25,100,116); (b) relative illumination requirements for the experimental settings including ambient lighting, blank or fixation field lighting, and stimulus field lighting (23,53,109,116); and (c) timing functions that are important to preclude lateral inhibition when subliminal and supraliminal stimuli are presented concurrently (e.g., prevent stronger stimuli from inhibiting weaker stimuli (21,23,26)). A more extensive critique of methodological and procedural issues in subliminal perception and subconscious processing research is presented later in this review.

In recent years, the methodologies and procedures employed in subliminal perception and subconscious processing research have become increasingly sophisticated (5,25,41,73,75,90,136,137). With greater research attention, more and more relevant variables are being identified and these variables are being measured with greater precision. Equally important, the research paradigms have improved to provide better control of the important variables and of factors that might confound the experimental process or findings.

The recent research on acquiring and processing subliminal visual information has effectively utilized stereoscopes, multifield tachistoscopes, and computer-controlled video terminals with pattern masking techniques. Precise timing and control equipment as well as specialized eye pieces and polarized filters supplement the basic experimental apparatus. In short, advances in both methodology and experimental apparatus now provide reasonable assurance of the fidelity of measures and controls used in research concerned with subliminal stimuli and subconscious processes.

ACQUISITION WITHOUT AWARENESS

Perceptual Sensitivity

Some of the early work on subconscious information acquisition processes produced convincing evidence of subliminal modulation of sensory-perceptual sensitivity and ongoing perceptual experience. This work demonstrated that when subliminal stimuli are acquired along with supraliminal stimuli, the additive effects are similar to those found in traditional anchor experiments involving multiple supraliminal stimuli. A summary of Bevan's subliminal anchor experiments (9) indicates consistent additive effects whether the subliminal and supraliminal sensory inflow involve electric shock, auditory tones, or visual objects. Nearly all anchor experiments and similar perceptual magnitude estimation studies showed that subliminal stimuli produce the same anchor effects as supraliminal stimuli (25).

The functional consequences of incorporating subthreshold information into visual, auditory, and somesthetic perceptions are quite consistent with Helson's (55) adaptation level theory. This theory specifies that stimulus perceptions are dependent upon the combined effects of antecedent stimuli to which the individual has become adapted. Adaptation level theory does not appear to rely solely on the conscious awareness of contributory stimuli, but rather on both subliminal and supraliminal sensory input.

Research of a different kind by Smith, Spence, & Klein (116) reaches essentially the same conclusion. Specifically, they also found that adding subliminal characteristics to an existing percept produced a change in perception consistent with the content of the subliminal stimulus. Subsequently, more complex replications have confirmed the Smith et al. findings (56,118).

For the present, let's consider the Smith et al. study and its obvious conceptual similarity to the anchor or magnitude estimations studies. These investigators visually presented the words HAPPY and ANGRY subliminally to a group of psychiatric patients to assess the impact of subconscious information on the perception of an expressionless face. The subliminal stimuli were presented well below a threshold tailored to each individual (about 4 msec for most subjects). Judges later classified the subjects' perception of facial countenance into positive and negative reaction categories. The findings indicated that the meaning of words presented well below the level of conscious awareness influenced the perception of facial expressions.

Another general type of research that is relevant to the matter of subliminal perception and sensory-perceptual information acquisition concerns the work on subliminal influence across sensory channels and modalities. In this kind of empirical study, investigators attempt to measure changes in the sensory-perceptual activity of one sensory channel or modality arising from subliminal stimulation in another sensory channel or modality. Several experiments of this general type are reviewed to illustrate both the diversity of approaches and the congruity of the findings.

Dixon et al. (25) conducted a number of investigations that involved measuring sensitivity changes to one eye while presenting subliminal stimuli to the other eye (for a summary of this work, see Dixon (25)). This research utilized signal detection theory to distinguish subliminal stimulus effects from response bias. The general experimental paradigm is relatively straightforward; one eye receives subliminal stimuli and the other eye provides a measure of threshold change to a spot of light. Subliminality is attained by manipulating energy intensity rather than duration.

The results are very consistent across different studies (21,23,25,26,59). Subliminal stimuli administered to one eye produced threshold changes in the other eye. The significance of these findings is underscored because the experimental methodology precluded a response bias explanation for the findings.

Walker's binocular rivalry paradigm, (136,137,138), represents a refinement of methodology over the earlier Dixon work. This paradigm is very well suited for research in subliminal perception and sensory-perceptual information acquisition. Information from only one eye reaches conscious awareness; however, sensory inflow from the dominant eye (conscious processing) and the suppressed eye (subconscious processing) are acquired and processed. Any change in the stimulus to the nondominant eye triggers the rivalry response and reverses the functional response for acquiring and processing supraliminal versus subliminal information.

Walker (136) extended the empirical research on binocular rivalry and dichoptic viewing to the area of movement detection and the acquisition of subliminal movement information. A stereoscope with colored filters was used to present rival red and green stimulus fields to the right and left eyes respectively. (The red field was smaller than the green field to discourage fusing to cortical yellow and to preclude piecemeal rivalry in which the field's localized parts behave independently.) As alternations occurred between rival fields, subjects pressed one of two microswitches to indicate which field was dominant. Superimposed supraliminal and subliminal movement patterns were presented on the red field during both dominant and nondominant conditions. The number of alternations and average duration of the dominant and nondominant conditions were calculated.

The basic premise underlying Walker's (136) experiment followed the early work of Levelt (66). Levelt proposed that the duration of the dominant period in binocular rivalry was a function of the strength of the stimulus in the contralateral eye. In other words, the mean duration of dominance is not dependent on stimulus strength in the dominant eye but rather depends on a change in strength in the nondominant eye. Accordingly, Walker hypothesized that the addition of movement to the nondominant eye would increase the level of stimulation to that eye and cause an alternation in dominance.

The findings of Walker's research showed that the temporal course of binocular rivalry is sensitive to a subliminal moving stimulus within a suppressed or nondominant visual field. Both supraliminal and subliminal movement stimulation during the suppressed (nondominant) condition resulted in significant ($p<.05$) movement-induced effects (change in dominance). However, similar stimulation during the dominant condition failed to elicit the movement effect and, consequently, did not result in a change in dominance.

Since the detection of movement occurred for subliminal stimuli that were presented to a nondominant visual field, Levelt's supposition also seems to embrace sensory inputs below the level of conscious awareness. Hence, the thesis that any feature that contributes to the strength of a stimulus also influences the course of rivalry seems to apply equally to both subliminal and supraliminal sensory stimulation. The significance of this conclusion is underscored by the fact that the subliminal stimulus was not only presented below threshold but also to the nondominant visual field, providing a dual safeguard against phenomenal representation.

Walker and Meyer (138) conducted a follow-up study that confirmed that movement stimuli presented below the level of conscious awareness can be detected. In the more recent study, autokinesis was used as the dependent variable because of its sensitivity to the presence of additional information in the visual field. Supraliminal and subliminal moving patterns were superimposed on supraliminal autokinetic stimuli.

The investigators found that autokinesis was sensitive to the real movement of a surrounding pattern, even when that pattern was transmitted via subliminal stimulation. Moreover, supraliminal and subliminal stimulation had differential effects on the autokinetic phenomenon. Supraliminal movement stimulation resulted in the perception of movement in a direction opposite to that produced by the autokinetic situation alone. On the other hand, subliminal moving stimuli appeared to inhibit autokinesis, inducing periods of stationarity in the autokinetic movement cycles.

With respect to perceptual illusions, there is solid evidence that appropriate subliminal input can modify the nature of the illusion. Dixon has summarized studies that deal with illusions such as those described by Muller-Lyer, Zoellner, and Kanizsa (25,44,115,144). The findings from these research efforts indicate that the acquisition of subthreshold, nonmeaningful geometric designs can alter the organization and appearance of a perceived object.

Cross Modality Interaction

The foregoing research has concentrated on sensory channels within the same sensory modality (e.g., channels within the visual modality or channels within the auditory modality). Let's turn to the evidence regarding cross-modality interaction effects. Although in previous research it was demonstrated that a change in the sensitivity of one modality can be produced by concomitant stimulation of another modality, much of this work has been confined to supraliminal stimulation (33,70,130). The present concern, however, is with the interaction between supraliminal and subliminal information acquisition that occurs in different sensory modalities. Hence, the final class of experiments to be considered concentrates on the relationship between supraliminal perceptual fidelity in one sensory modality and the subconscious acquisition and processing of subliminal information in another sensory modality.

A number of studies concerned with multimodal subliminal and supraliminal information acquisition have provided valuable data on subliminal perceptual processes. Investigations of this type seek to determine: (a) under what conditions subliminal accessory stimulation in a nonprimary sensory modality enhances or hinders information acquisition in a primary sensory modality; and (b) whether subliminal accessory information in a nonprimary sensory modality can be used to improve information acquisition in a primary sensory modality. Of special interest are potential improvements in primary sensory modality information acquisition such as reduced sensory threshold, increased sensory-perceptual acuity, and enhanced perceptual fidelity.

Hardy and Legge (54) conducted two experiments that showed subliminal emotional stimuli presented to one sensory modality significantly interfered ($p<.001$) with detection performance in a different sensory modality. In one experiment, the visual detection threshold was raised by simultaneous auditory stimulation involving subliminal emotional words. Similar results were obtained when the experimental roles of the two modalities were reversed and subliminal emotional stimuli were presented visually to determine the impact on the auditory detection thresholds.

The two experiments by Hardy and Legge indicate that the threshold of one sensory modality can be altered by subliminal stimuli applied to another modality. Both visual and auditory thresholds to supraliminal, neutral stimuli were increased as a result of the acquisition of subliminal emotional stimuli by a different sensory modality. The investigators suggested that the resultant higher threshold for supraliminal stimuli was due to increased internal noise caused by the emotional subthreshold inputs, partially masking the supraliminal sensory inflow.

Accessory Stimulation

The research on accessory stimulation also supports the validity of subliminal information effects. For example, in one study, an assessment was made of the effects of both subliminal and supraliminal auditory accessory stimulation (white noise) on a visual detection task (149). This study was conducted using signal detection theory (128,129) to separate changes in sensory sensitivity (d') from nonsensory factors (ß) such as attitudes and motivation. The experimental design included six levels of white noise (three above threshold and three below threshold), along with a "no-noise" control condition.

The results indicated that subliminal accessory stimulation was just as effective as supraliminal accessory stimulation in producing an increase in visual detection sensitivity. Mean sensitivity was greatest for accessory stimulation at +15 db above threshold and -15 db below threshold. Further, accessory stimulation did not appear to affect psychological response factors that typically influence signal detection (ß variables). Thus, it seems that accessory stimulation effects are restricted to changes in sensory sensitivity (d') rather than to differences in response style.

It may well be that subliminal noise at particular energy levels sharpens the signal-to-noise ratio by attenuating, dampening, or canceling internal noise. If this is the case, considerable individual differences should exist as a function of differential internal noise levels. It is known, for example, that interindividual variability in internal noise states exist as a result of the interactive consequences of motivation, arousal, stress, anxiety, fatigue, need states, etc. Research on the interaction of internal conditions with the effects of subliminal accessory stimulation could make a valuable contribution toward understanding the balance required between internal noise states and accessory stimulation in order to optimize performance.

A study under the tutelage of Zenhausern used perceptual illusions as the dependent variable (145). Although this study is a variant of the perceptual illusion work discussed earlier in this section, it was conducted within the context of a multiple modality, accessory stimulation investigation. Both subliminal and supraliminal auditory stimulation were employed to evaluate possible differential effects on visual illusions.

Six levels of accessory stimulation in the form of white noise (three above threshold and three below threshold), as well as no-noise condition, were introduced during a visual evaluation task involving trapezoid illusions (task explained in reference 149). The findings revealed that only very extreme subliminal stimulation (-30 db below threshold) produced significantly ($p<.01$) more illusory experiences than the no-noise situation. In this case, the authors suggested that subliminal stimulation decreased attention and, as a result, increased the perception of illusion. Another interpretation of the results might be that subliminal stimulation increased sensory sensitivity to all cues, even those that were illusory or misleading.

Conclusions: Acquisition Without Awareness

The research reviewed in this section supports the conclusion that subthreshold information can be subconsciously acquired and influence sensory-perceptual information acquisition processes. Stimuli too brief or too weak to achieve conscious awareness appear to influence perception and the incoming stream of stable, supraliminal information. It is clear that subthreshold sensory information is incorporated into a broad spectrum of perceptual activities.

In this section, a variety of experiments was assessed in three principal areas. Specifically, an evaluation was made of the influence of subliminal stimulation and subconscious information acquisition on (a) sensory-perceptual threshold and sensitivity, (b) interchannel and intermodality perceptual fidelity, and (c) subthreshold accessory stimulation effects. The empirical data evaluated demonstrate that meaningful subliminal perceptual effects can occur in all three areas of interest. Table 1 summarizes the conclusions reached from these data and also provides reference citations to the research studies on which the conclusions are based.

TABLE 1

Subliminal Perception and Sensory-Perceptual Acquisition

Major Findings
• Subliminal electric shock increased perceived intensity of supraliminal shock.
• Subliminal visual stimuli altered perceived visual size.
• Subliminal auditory stimuli increased perceived sound intensity (loudness).
• Perceptions of ambiguous human figures were influenced by subliminal pictures and symbols.
• Subliminal words affected perceptions of facial expressions.
• Subliminal visual movement induced changes in the temporal course of binocular rivalry.
• Subliminal stimulation influenced movement detection performance.
• Subliminal stimulation inhibited autokinesis.
• Subthreshold geometric designs modified perceptions of stimulus objects.
• Subliminal stimulation increased illusory perceptions.
• Subthreshold information in one sensory channel produced threshold changes in a separate sensory channel.
• Subliminal information presented to one sensory modality affected signal or target detection performance in another sensory modality.
• Subliminal auditory accessory stimulation increased visual detection sensitivity.

Key References: 9,10,11,13,15,21,22,23,24,25,26,31,32,33 44,54,56,57,58,59,64,115,116,118,136, 137,138,144,145,148,149

PROCESSING WITHOUT AWARENESS

Perceptual-Cognitive Processing

There is solid research evidence to support the conclusion that subliminal information can influence more complex perceptual-cognitive processing, as well as the information acquisition processes just discussed. We will report evidence relevant to perceptual-cognitive processing next. We will give particular attention to the influence of subthreshold information relating to higher order analytical and judgment processes. In addition, subconscious information analysis and processing capabilities will be assessed.

In this section, research is reviewed from a variety of investigations concerned with the subconscious perceptual and cognitive analysis of sensory inflow. This research has been classified into eight categories addressed in the following sequence: accessory stimulation, binocular rivalry and dichoptic viewing, dichotic listening, lexical decisions, subconscious memory, subconscious motivation, and altered states. The impact of subthreshold information processing on cognitive analysis, judgment, decision making, and psychomotor performance was of special interest throughout the review of research associated with these categories.

Accessory Stimulation

One experiment by Zenhausern and his colleagues focused on the differential impact of subliminal and supraliminal accessory stimulation on psychomotor response (147). This experiment introduced white noise levels, ranging from -30 db below to +70 db above an individually determined auditory threshold under three different reaction time conditions. Only the +70 db noise condition resulted in reaction times significantly ($p<.05$) faster than the no noise condition. The investigators suggested that the failure of subliminal stimulation, and other levels of supraliminal stimulation, to produce the expected sensitizing effect was due to the arousing nature of the task. Since reaction time tasks are inherently arousing for most individuals, these tasks may have triggered an activation level so high that only very strong accessory stimulation was able to influence performance.

Next, Zenhausern examined both subliminal and supraliminal accessory stimulation in relation to problem solving (146). As with all of his studies, Zenhausern tailored the baseline white noise threshold and corresponding accessory stimulation levels to each individual subject; the resultant stimulation levels ranged from -30 db below threshold to +60 db above threshold. The performance criterion was a problem-solving task of moderate complexity (Stencil Design Tests (3)). This criterion task involves the replication of printed designs and requires the use of sensory, perceptual, intellectual, and motor abilities.

The principal finding that emerged from the problem solving study concerned the variable effects of different levels of accessory stimulation. Problem resolution speed was maximum at -10 db below threshold, probably because this level provided minimum arousal and virtually no conscious awareness and, hence, no distraction. Performance improved again at +60 db above threshold indicating that at this point the level of arousal overcame the noise distraction effects. For some reason, +35 db above threshold and -30 db below threshold caused a performance decrement (increased problem resolution time) when compared with other levels of subliminal and supraliminal accessory stimulation and the no-noise situation.

The work of Zenhausern and his associates, taken as a whole, appears to indicate that accessory stimulation does not have a uniform effect. It seems that the levels of stimulation, both subliminal and supraliminal, are important. Moreover, the specific task involved, the abilities required to perform the task, and the individual's internal noise level are all likely critical in determining the exact effects of accessory stimulation. For example, Zenhausern's research indicates that for purely sensory tasks, subliminal and supraliminal stimulation were facilitatory (149); for perceptual tasks, only subliminal stimulation had an effect (145); for psychomotor performance, only supraliminal stimulation was effective (147); and for problem solving, the results were variable (146), as might be expected for complex multimodal, multiability tasks.

Binocular Rivalry and Dichoptic Viewing

The dichoptic viewing and binocular rivalry experiments that were discussed earlier in relation to subliminal information acquisition are also applicable to the matter of subconscious information processing. It will be recalled that in the binocular rivalry paradigm, a stimulus of specified intensity is presented to one eye while another stimulus of greater intensity is presented to the other eye. When a stimulus is presented to one eye alone, the stimulus is clearly visible; however, if a stimulus of higher intensity is presented to the other eye, it completely suppresses phenomenological representation of the first stimulus. In other words, a stimulus consciously perceived by one eye is masked when the other eye is subjected to contiguous stimulation employing a brighter image. This suppression does not occur if both stimuli are presented to the same eye.

Using the binocular rivalry paradigm, Somekh & Wilding (118) replicated the Smith et al. (116) study of subliminal perception. They asked subjects to rate neutral facial expressions using a three-category (miserable, neutral, cheerful) forced-choice indicator while they were simultaneously presented with subliminal information consisting of one of two different word types. One type involved the critical stimulus words (HAPPY and SAD), while the second type consisted of structurally similar words (HURRY and SAY, and CARRY and HAD). The two different types of words were used to separate the effects of word meaning or semantics from the effects of word structure or form. The binocular rivalry condition was created with a stereoscope fitting with eyepiece

lenses and filters for masking. The masked eye was presented a dimmer image containing the subliminal stimulus word and the target eye received a brighter, sharper image of a face with a neutral expression.

The findings of Somekh and Wilding's investigation showed that subliminal stimulus words influenced semantically related perceptual-cognitive analysis at least as much as when the same words were presented supraliminally. When both stimulus word and picture were above the threshold of conscious awareness, the structure or form of the words seemed to have more impact on judgments of facial expression than word meaning. For example, less common words of similar shape or form but different meaning often had the same effect as the expected word (HAPPY or SAD). Conversely, when the stimulus words were presented below the level of conscious awareness (subliminally), it appeared that word meaning was the basis for analysis.

The results obtained by Somekh and Wilding support Dixon's (23) contention that individuals will respond to appropriate structural equivalents when the stimulus remains above the threshold of conscious awareness. Thus, it would appear that subliminal information is processed quite differently than supraliminal information, a conclusion not easily explained by partial cue explanations for subliminal stimulus effects. If supraliminal or phenomenal sensory stimuli are discriminated primarily by structure and subliminal stimuli are distinguished mainly by meaning, it would be valuable to understand the underlying mechanisms. Such a state of affairs suggests that supraliminal stimuli are processed logically and analytically using structural relations as the dominant substance; whereas subliminal perceptual processes are prelogical, involving intuitive, inductive, and creative activities which operate mostly in a semantic mode.

A cross-modal replication of the Smith et al. (116) study by Henley (56) sheds further light on the subconscious analysis of subliminal information. In this study the effects of subthreshold auditory cues were assessed in relation to subjective judgments of supraliminal visual pictures. In brief, Henley's investigation addressed the question of whether subliminal disambiguating information processed by an unattended sensory modality could influence supraliminal information being processed on a <u>different</u>, attended sensory modality. The Smith et al. paradigm was followed except that the subliminal stimuli (the words HAPPY and SAD) were presented via the auditory rather than the visual modality. The subjects were required to make perceptual-cognitive judgments regarding the countenance of a supraliminal neutral face presented visually.

Henley's experiments demonstrated the capacity of subliminal cues to influence reaction time. This finding is consistent with other work involving dichoptic viewing and dichotic listening (16,25,54,67,68,73,90,118). In these other studies, subliminal cues resulted in faster reaction times in visual judgment and lexical decision tasks. Although the subliminal auditory cues used by Henley improved reaction time, they did not appear to influence visual judgment. He suggests that such an effect might be caused by a visual

stimulus that is less ambiguous and, consequently, more compelling than intended, thereby reducing receptivity to the subliminal auditory input.

In an extension of research involving semantic interference between supraliminal and subliminal stimuli (67,133), Philpott & Wilding (90) conducted two experiments to explore the relationship between semantic association and response latency. Using the binocular rivalry paradigm, a dim stimulus was presented to one eye and a bright stimulus was presented to the other eye to suppress awareness of the dim stimulus and produce a perception that the bright stimulus is viewed by both eyes. The primary (bright) stimuli were various shapes, colors, and words; the secondary (dim) stimuli were various shapes and words, each bearing a different semantic relationship to primary stimuli (e.g., synonymous, conflicting, abstract, or no secondary stimulus).

The findings of Philpott and Wilding's experiment demonstrated that the degree of interference is a function of the relationship between the supraliminal and subliminal stimuli. The subliminal stimuli most similar to the primary stimuli induced the longest response latencies. The investigators concluded that stimuli related to meaning compete for common analyzing mechanisms. Thus, it seems that parallel processing of information is possible only when different analysis processes are involved; and, in the case where both supraliminal and subliminal information are loaded with meaning, a major information processing chokepoint may occur.

The semantic interference reported by Philpott and Wilding in the dichoptic viewing situation is consistent with the longer response latencies found by Lewis (67) for synonyms and also for sequentially associated words vis a vis antonyms and unrelated words, as well as with parallel findings involving similar meaning in pictures and words (133). There is reason to believe that it is easier to filter secondary stimuli and minimize their interference effects when one is aware of their presence (23). Accordingly, the interference of secondary stimuli is thought to be greater when they are semantically similar to primary stimuli and also below the level of conscious awareness (25,90).

Dichotic Listening

Research conducted by Lewis (67) is also representative of the evidence indicating that information is subconsciously analyzed for meaning prior to storage and prior to admission to conscious awareness. His dichotic listening studies employed a methodology that ensured both adequate control and a sensitive measure of information processing effectiveness. Subjects were required to shadow a message (consisting of single syllable, unrelated words) in the attended ear at a rate of one word every 2/3 second (667 msec). This rate does not permit an attention shift to the unattended ear without losing a part of the attended message. At the same time, words were presented to the unattended ear that were related to the primary word in various ways.

The results of the Lewis experiments indicated that words that were presented to the unattended ear altered reaction time to words presented

simultaneously to the attended ear. The semantic similarity of words was more crucial in producing interference than was their associative strength. Thus, stimulus information that was received by an unattended sensory channel seemed to be semantically analyzed early in the information processing sequence.

Other research using experimental designs with dichotic tasks further clarified the Lewis findings. For example, MacKay (71) found that certain words on the unattended channel can disambiguate a sentence on the attended channel. In addition, Henley and Dixon (58) showed that the imagery evoked by music presented to one ear was affected by words presented subliminally to the other ear as long as the music and words were processed over contralateral pathways by hemispheres relevant for their processing.

Lexical Decisions

During the 1980s, there were a number of independent studies that provided important data confirming the reality of subliminal perception and related subconscious processing capabilities. Equally important, these studies furnished valuable information about functional properties of subconscious analytical processes. The experiments on which these more recent findings are based all employ some form of the visual pictorial or lexical decision paradigm.

Generally, in the pictorial or lexical decision paradigm, there is a brief tachistoscopic exposure of a priming cue intended to bias a supraliminal signal. The priming cue is immediately followed by a pattern mask to ensure that the cue is truly below conscious awareness (subliminal). The use of this paradigm in its various forms is further explained, as appropriate, within the context of specific investigations to be discussed next.

The nature of subconscious analytical processes was explored in a series of six experiments by Fowler and her associates (41). An important objective of these experiments was to determine the key temporal factors associated with three aspects of information processing; analysis of meaning or significance, analysis of physical features or structure, and object identification. In order to ferret out the time-course differences related to crucial perceptual-cognitive processing events, an experimental paradigm was employed that used varied stimulus-onset asynchronies (SOAs) between the primary stimulus and the pattern mask.

Priming stimuli were presented over a range of SOAs and the effects on consequent lexical decision performance determined. Priming stimuli were words related to target words in one of three ways: semantically, phonetically, or graphically. By varying the SOA or time between onset of the priming word and onset of the pattern mask, the influence of the prime on the target word was determined as a function of the time permitted for perceptual-cognitive processing. There were two issues of particular importance: (a) the type and amount of information processed before termination by the mask and (b) the priming effects on

processed information, especially with respect to target word identification speed and accuracy.

A number of meaningful results surfaced from the six experiments conducted by Fowler et al. Individuals were clearly more sensitive to the semantic properties of subliminal priming stimuli than they were to phonetic and graphic characteristics. Additionally, semantic judgments were made at SOAs that were too brief to make judgments of physical features. It appears that the semantic properties of masked words are known (processed) decidedly earlier than the physical properties.

Both reaction time and accuracy were significantly enhanced by subliminal semantic priming cues ($p = .012$ and $p = .002$, respectively). Also, reaction time was significantly faster when subliminal priming stimuli were used than with supraliminal priming stimuli (35 msec faster, $p = .07$). Another interesting finding was the significant interference effects of phonemic and graphemic priming stimuli with regard to lexical decision reaction time and accuracy. The phonemic/graphemic interference effects on reaction time and accuracy occurred for both the supraliminal (no-mask) condition ($p_s = .016$ and .03, respectively) and under the subliminal masking conditions ($p_s = .02$ and .03, respectively). Thus, the findings illustrate similar phonemic and graphemic interference effects for the acquisition and processing of both conscious and subconscious information during lexical decision making.

A number of salient conclusions resulted from the findings of the six Fowler et al. experiments. The composite results are quite explicit that individuals make accurate semantic judgments at SOAs too brief to make decisions about the form or even the visual presence of the priming stimulus. One logical explanation for the findings is that the central mask interrupts perceptual-cognitive processing at the point determined by the SOA. However, since individuals were able to extract meaning with SOAs as brief as 10 to 20 msec, a more plausible interpretation is that pattern masking prevents conscious awareness but not perceptual-cognitive analysis.

Two experiments by McCauley and his colleagues also indicate that a considerable amount of meaning is extracted from stimuli before sufficient information accrues for explicit conscious identification (75). In these experiments, individuals labeled target pictures that were preceded by other related or unrelated subliminal priming pictures. The priming pictures were presented at varying durations, ranging from above the identification threshold to well below.

The results demonstrated that response latencies to targets were significantly faster ($p<.001$) when the priming stimulus was semantically related to the target. Moreover, the target labeling reaction time when the priming stimulus was well below threshold was faster than when the priming stimulus was above threshold (742 msec vs 782 msec, $p<.01$). The viewing time required to permit subconscious semantic analysis and priming was between 18 and 37 msec. This subliminal semantic processing latency was nearly 1.5 times shorter than the latency for conscious identification, suggesting that the two processes are quite distinct.

The experiments of McCauley et al. indicate that information presented at durations too brief for conscious awareness can be utilized to increase target identification speed. This capacity to extract meaning subconsciously from a stimulus array apparently occurs prior to the conscious identification of the priming stimulus. These findings on subliminal attentive mechanisms are consistent with the known properties of selective attention and visual search, particularly with respect to the automatic vis a vis controlled information acquisition and processing systems (98,99,107).

The longer latencies for supraliminal vis a vis subliminal priming stimuli found by McCauley et al. appear to reflect the limited capacity processing chokepoints that are associated with conscious awareness and controlled processing. Conversely, the rapid priming effects produced by related subliminal stimulation are very similar in process to the automatic perceptual processes that are described in selective attention and visual search studies. This parallel observed between subconscious and automatic suprathreshold perceptual-cognitive processing and other important components of the conceptual and empirical linkages between subliminal perception and selective attention are addressed in a separate review.

There is more definitive evidence for the semantic analysis of information below the level of conscious awareness in the work of Marcel (72,73,74). This research supports the independence of perceptual-cognitive processing operations concerned with the extraction of meaning or significance versus those involved in the determination of physical properties and the identification of objects. Knowledge of stimulus lexical or semantic properties was consistently exhibited at durations too brief to describe physical features or explain the source of such semantic insight.

Marcel's (73) more recent work involved five experiments which attempted to precisely define the parameters of subconscious analysis and perceptual-cognitive processing. Several variations of the lexical decision task were utilized throughout the five experiments. Both central masking with a dichoptic pattern mask and peripheral masking via monoptically presented noise to the dominant eye were utilized to disrupt processing of visually presented information. Peripheral masking constitutes an energy override function which obliterates all processing, conscious and subconscious. Conversely, pattern masking, which is an onset-onset function employing stimulus onset asynchronies, allows subconscious analysis but precludes conscious awareness.

The general experimental design employed by Marcel embraced a variety of options that made direct comparisons possible between subconscious and conscious processing. Either two words or two strings of letters were tachistoscopically presented under three basic conditions: (a) interrupted by a peripheral mask (noise) presented to the dominant eye, (b) interrupted by a pattern mask presented dichoptically, or (c) presentation to the dominant eye without interruption. A range of SOAs was used in combination with varying relationships between the words or letter strings (e.g., semantic or graphic) to determine the sequence, time function, and extent of awareness associated with perceptual-cognitive processing.

There are several interesting results from Marcel's experiments:

- Extensive individual differences were found in visual detection SOAs. For example, the point at which stimulus detection performance diminished to 60% accuracy ranged from 110 down to 20 msec.

- As the SOA was reduced, visual detection performance decrements occurred first, followed by graphic similarity judgment. The last capability to be influenced by SOA reduction was semantic judgment. When SOAs diminished to the point that individuals lacked information to detect stimulus presence, they were still able to make correct graphic and semantic judgments on 80-100% of the trials. With additional reduction in time between stimulus and mask onset, graphic decision accuracy fell to between 60 and 70%, whereas semantic decision accuracy remained above 80%.

- Subliminal access to graphic and semantic information appeared to be independent; semantic information was processed more reliably and with greater resistance to pattern masking.

- Pattern masked words were not consciously detectable nor reportable; thus, they were effectively denied access to conscious awareness. Nevertheless, these words were subconsciously acquired and their semantic or lexical properties analyzed below the level of conscious awareness.

- A comparison of peripheral noise or energy masking with central or pattern masking revealed significant differences in effects ($p<.001$). When pattern masking was interspersed between semantically associated words, reaction time was 56 msec faster than when the words were not related. However, when peripheral energy masking was interspersed between semantically associated words, virtually no advantage (4 msec) over nonassociated words was manifested. As a baseline comparison, a 62 msec advantage was found for semantically associated words when no mask conditions were employed. These results indicate that energy masking obscures nearly all information peripherally, precluding both subconscious and conscious information acquisition and processing, whereas pattern masking permits subconscious access to meaning and certain figural properties, but prevents entry to conscious awareness.

- The repetition of pattern masked words (subliminal acquisition) monotonically increased the semantic association effect, but it had no influence on the probability of detection. This repetition effect may be the consequence of cumulative activation caused by associative priming.

Additional knowledge about subliminal analysis capabilities is found in Balota's (5) research. He investigated the priming influence of pattern masked stimuli on lexical decision latency using unusually long SOAs (350-2000 msec). His intent was to design an episodic memory

task sensitive to the degree of cognitive activation produced at encoding. Accordingly, the experimental paradigm coupled a semantic priming task to an episodic context recognition task.

Balota's investigation was carefully designed to control for a number of factors considered crucial to subconscious semantic analysis of sensory inflow. For example: (a) tachistoscopic priming, target, and masking stimuli were presented dichoptically to ensure central masking; (b) the context of the subliminal priming stimulus as related to the target was varied to assess the direction of spreading activation in terms of encoding and semantic associates; (c) both homographs, words spelled alike but with different meanings, and nonhomographs were used to control for idiosyncratic effects of polysemous (multiple meanings, ambiguous) words; (d) three types of priming stimuli were employed to gauge the advantage of subconscious semantic analysis; and (e) a range of SOAs permitted evaluation of the subliminal spreading activation effects of relatively brief SOAs versus the effects of allocating attention to the priming stimulus as found with the longer supraliminal SOAs. With respect to longer supraliminal SOAs, the limited capacity conscious attentional process is believed to focus attention on the precise area of memory where the priming stimulus is located. This focus is in contrast to subconscious spreading activation to regional semantic or context associates of the priming stimuli as produced with subliminal or very brief SOAs.

Balota's findings are compatible with expectations. The composite analysis of target reaction time data indicates that individuals were faster when processing subliminal information (616 msec) than when processing supraliminal information (647 msec). Individuals also responded faster to the target words when the priming words were semantically related than when they were neutral or unrelated, a finding that held for both subliminal and supraliminal priming stimuli. Error rates were higher when priming stimuli were either unrelated to the target or neutral than when priming and target words were semantically related. In cases involving subliminal priming stimuli, reaction time to target words was fastest when the SOA was short and when the priming cues were related semantically to the target and nonhomographs.

An especially interesting finding concerns the influence of priming stimulus context on target response. When the priming stimulus was subliminal, there was the expected semantic priming effect but no evidence of context influence based on episodic memory recognition. In the case of supraliminal priming stimuli, however, both semantic and episodic recognition context influenced target response.

In summary, it appears that acquisition of raw subthreshold visual information triggers subconscious semantic analysis which spreads automatically to related representations. This process produces a priming effect without conscious awareness of the original stimulus. When the SOA is increased to the point where the individual becomes conscious of the priming stimulus, an attentional focusing response occurs in addition to automatic semantic activation. This attention focus which characterizes conscious awareness, seems to include concentration on both the priming stimulus and its context.

Conclusions: Processing Without Awareness

Table 2 summarizes the findings that apply to processing without awareness and lists references to the research which produced the findings. The evidence convincingly demonstrates that subthreshold information can influence the perceptual-cognitive processing of suprathreshold information. Moreover, the effects of subconscious analysis of subliminal information are manifested in a variety of overt responses including the semantic orientation of verbal behavior, linguistic analysis, visual and auditory judgments, lexical decisions, problem solving, and decision speed and accuracy. This representation of subliminal information in overt responses occurs despite the fact that the precipitating stimuli remain below the level of conscious awareness.

Subconscious Memory

Dixon's (25) excellent treatise on preconscious processing presents evidence in support of subconscious interaction between sensory inflow and information stored in long-term memory. He concluded that all three memory systems (sensory, short-term, and long-term) can function on either a conscious or subconscious level. Principal psychological activities involving memory (e.g., learning, information storage, retrieval, and remembering) are viewed as having both conscious and subconscious components.

A crucial aspect of memory involves the process of storing acquired information and the organization of that information in the long-term memory store. The cumulative research data presented in Dixon (23,25) and related evidence merit several conclusions with respect to memory systems and subconscious information analysis, organization, storage, and retrieval. Eight principal conclusions are summarized in Table 3 which also lists reference citations germane to the empirical research base.

TABLE 2

Subliminal Perception and Subconscious Processing

Major Findings
• Subliminal auditory and visual stimuli influenced estimating accuracy.
• Subliminal verbal stimuli evoked symbolic associates.
• Subliminal verbal stimuli modified descriptions of words presented above threshold.
• Subliminal stimulus meaning determined selection of associative responses.
• Subthreshold stimuli enhanced existing associations between stimulus and response.
• Subliminal stimulus words (both auditory and visual channels) facilitated semantically related responses.
• Subthreshold words and pictures influenced word estimation accuracy and retrieval of information from long-term memory.
• Subliminal stimulus words influenced semantically related visual perceptions.
• Subliminal stimulus words aided in the clarification of supraliminal auditory information.
• Subthreshold stimulus words affected response time to supraliminal auditory stimuli.
• Subliminal auditory clues resulted in faster response times in performing visual judgment tasks.
• Subthreshold visual stimuli similar in meaning to supraliminal visual stimuli increased response latency.

TABLE 2 (Continued)

Subliminal Stimulation and Subconscious Processing

Major Findings (Continued)
• Subthreshold stimulus words influenced imagery evoked by music.
• Unreported peripheral stimuli subconsciously biased interpretation of homographs.
• Supraliminal reward and punishment (electric shock) increased discrimination learning of subliminal geometric forms.
• Supraliminal (but not subliminal) auditory stimulation (white noise) enhanced psychomotor reaction time.
• Problem resolution speed improved under certain levels of subliminal auditory stimulation (white noise).
• Subliminal priming cues increased accuracy and reduced reaction time in a lexical decision task.
• Subthreshold cues semantically related to target words increased target word identification speed and accuracy.
• Subthreshold priming cues produced faster target response time than suprathreshold cues.
• Extensive individual differences were found in subliminal visual processing performance during a lexical decision task.
• Semantic and figural data were reliably extracted from subliminal target stimuli prior to conscious identification.

Key References: 5,14,23,24,25,41,56,58,67,71,72,73,74,75, 78,79,82,83,84,90,91,92,93,118,119,133, 142,146,147

TABLE 3

Subconscious Memory Systems

Principal Conclusions
• Memory systems are especially fine tuned to the affective content of sensory inflow, providing for a complete semantic assessment of the information.
• Highly significant or emotional information acquired at subthreshold levels evokes neurophysiological and behavioral responses without conscious awareness. These responses seem to reflect subconscious semantic analyses accomplished within the long-term memory system.
• Preconscious processing involves mediating the information interface between afferent inflow and appropriate memory templates, structures and schemata. Special importance is attached to the emotional classification of sensory inflow through subconscious interaction with long-term memory.
• Long-term memory conducts a full semantic analysis of sensory inflow including assessments of emotional meaning, personal significance, and task and situational importance.
• Subliminal sensory inflow activates a lexical-semantic network in long-term memory; analysis of phonemic, graphic, and physical/spatial features are also automatic and subconscious.
• Subconscious semantic analysis and processing within long-term memory involves spreading activation to lexical associates as well as elaboration of images. Although multiple meanings may be activated subconsciously in long-term memory, only one meaning at a time may enter conscious awareness.
• Long-term memory schemata are organized primarily in terms of information importance and significance as determined by the individual.
• The accessibility of information in long-term memory or ease of retrieval is largely dependent on emotional meaning, personal significance, task/situational importance, motivational and drive relatedness, familiarity, and subconscious defenses.

Key References: 18,19,20,25,36,48,49,54,63,74,80,81,82,83, 84,85,92,94,95,106,119,120,121,122,123, 132,134,135,140,143

The meaning of subliminal information, particularly its emotional significance and its importance to the task or situation at hand, appears to activate appropriate emotionally charged memory content and arousal control mechanisms in long-term memory (23,25). The effects of this subconscious analysis and activation process are typically reflected in both overt behavior, as demonstrated in the preceding sections, and in neurophysiological activity. An assessment regarding the neurophysiological basis for subliminal information acquisition and analysis is in preparation and will be the subject of a separate review.

Dixon's (25) concept of dual memory systems, one conscious and one subconscious, is congruent with other known characteristics of memory. In addition to information acquisition, organization, and storage in long-term memory, other aspects of memory can also function subconsciously. Learning, for example, can be either conscious and intentional or subconscious and incidental. Retrieval is also comprised of subconscious as well as conscious processes.

The process of remembering or calling up stored information involves converting subconscious into conscious information; or in Dixon's terms, translation across the "fluctuating, permeable or semipermeable, boundary between conscious and preconscious" (25, p. 84). The "tip of tongue" phenomenon in which an individual experiences knowing something, but being temporarily unable to describe it, epitomizes the fluctuating permeability of this boundary. Common day-to-day experiences are replete with examples of transient difficulties in the translation of information from subconscious neurophysiological storage mechanisms to phenomenal representations.

Subconscious Motivation

Since consciousness has limited capacity, it is oriented toward the representation of high priority external and internal stimuli of primary importance for survival and coping behavior. From this point of view, consciousness reflects the top down influence of motivational factors including drive states, psychological needs, cognitive set, emotions, and expectancies. The motivational factors combine with task and situational conditions that are extracted from sensory inflow to orient consciousness.

Two issues have particular interest: (a) the influence of subthreshold sensory information on motivational factors and (b) the impact of subconscious motivations on conscious behavior. Since many of the underlying motivational drivers are largely subconscious, they are difficult to attack scientifically. However, the available evidence suggests that the emergence of stimulus-independent motivational factors is primarily a function of the strength of relevant underlying needs and the relative lack of competing sensory input (25).

Research evidence concerned with subliminal perception and physiological needs suggests that subthreshold stimulation can give direction to overt behavior provided the need-directed behavior is not contrary to other strong motivational states (23,25). When continuing

drive states activate a specific response schema, the threshold for related information is reduced, thereby increasing the likelihood that relevant subliminal stimulation could be effective in influencing behavior. Further, a specific affective or emotional state, when it is combined with a subliminal stimulus, can have a selective facilitation effect upon relevant drive schemata. This appears to be the case regardless of whether the affective state is social in nature (e.g., feelings of self-confidence) or physiological in origin (e.g., feelings of hunger). Moreover, when psychopathological affective states are involved with related drive schemata, subliminal stimuli are more effective than supraliminal stimuli because they circumvent the censorship and constraints of consciousness.

The early research of Spence and his associates explored motivational states and priming related behavior using subliminal stimulation (43,50,121,122). Results from this formative work indicated that overt responses were pervaded with drive connotations. It is germane to the present discussion to underscore the fact that motivational states comprise one of the major top down factors impinging on information acquisition and processing activities. Emotional meaning and need-related significance, as a consequence, are central to the subconscious analysis of sensory inflow. The reciprocal nature of this process is manifested as the content of subthreshold inflow modifies feelings, emotions, and motivation states.

Both external sensory information and internal stimuli such as that originating in long-term memory carry two types of content: (a) conceptual or informational content and (b) activational or drive-related content reflecting the significance and importance of information (25). The motivational and affective type of content serves three primary purposes as noted by Dixon: an alarm signal for behavioral arousal, an orienting stimulus for conscious attention, and a motive for organizing and directing behavior.

There is ample evidence that subthreshold information is subconsciously analyzed for meaning and can elicit emotional and affective responses (18,25,27,28,48,49,56,112,113,114,116,118,132). Similar conclusions can be found in research examining subliminal psychodynamic activation which will be addressed in a separate review, now in preparation. The combined data demonstrate that semantic assessment of sensory inflow is predominantly concerned with classification based on emotional significance and importance. The data further indicate that the classification process results from subconscious interaction between subliminal sensory information and long-term memory.

In summary, the results of investigations concerned with subliminal perception and motivational states support at least four major conclusions:

- Subliminal stimuli can activate drive-related memories when individuals are made aware of their current drive state through supraliminal priming. In this regard, priming is believed to act in a disinhibitory manner on stored information.

- The emotional connotations and personal significance of subliminal stimuli can be analyzed, extracted, and responses can be initiated prior to, or without, achieving conscious representation.

- Subconsciously acquired and processed information can generate and modify activational states, emotions, and feelings.

- Measures of autonomic and neurophysiological responses are especially valuable in assessing the motivational and emotional components of subliminal information because such measures are generally outside the realm of voluntary control and tend to be less contaminated by extraneous conscious input.

Table 4 summarizes the major findings on subliminal perception and motivational states and lists references to research studies that support these findings.

TABLE 4

Subliminal Perception and Motivational States

Major Findings
• Subliminal stimulation not contrary to strong physiological drives or motivational states influenced overt behavior.
• Subliminal stimulation activated drive-related memories when accompanied by supraliminal priming which heightened awareness of current drive state.
• Physiological needs and affective states operated selectively on memory, lowering the response threshold for related subliminal perception.
• Subliminal stimulation modified the level of drive motivation or arousal.
• Subthreshold information and physiological drive interacted to influence sensory systems at the preconscious state of information acquisition and processing.
• Subliminal stimulation interacted with physiological needs to facilitate recall of learned associates.
• The drive or physiological need connotations of subthreshold information dominated verbal responses.
• Supraliminal priming and motivational set both increased receptivity to appropriate subliminal stimuli.
Key References: 23,25,43,48,49,50,92,116,120,121,122,123

Altered States

Subliminal perception and endogenously generated altered states are similar in the sense that both presuppose a lack of awareness of external stimulation. Changes in attentional states comprise another common marker of subliminal perception and altered states of consciousness. Top-down processes relinquish, in both cases, substantial control to bottom-up spreading activation (25). Many of the endogenously generated phenomena (e.g., normal waking imagery, eidetic imagery, hypnogogic and hypnopompic imagery, normal night dreams, and visual hallucinations) also similarly depend on a state of neocortical desynchronization (23).

In studying dream content and similarities between dreaming and subliminal perception, it is important to distinguish between Rapid Eye Movement (REM) and non-REM sleep. During REM sleep, dreams are vivid, bizarre, coherent, and memorable. REM dreams seem to reflect deeper primitive thought processes, while non-REM dreams are more similar to the normal waking thought processes (25).

During REM sleep, the state of cortical activity is very similar to that associated with active cerebration in the waking state (23). REM sleep is also characterized by a high arousal threshold, an almost deafferentation from external stimulation, and nearly total blockage of motor outflow (other than the REMs per se). Yet, despite a high behavioral arousal threshold to insulate the individual from disturbing external stimuli, REM sleep, as is the case with non-REM or slow wave sleep, does not prevent the occurrence of differential EEG responsiveness (K complexes) to significant verbal stimuli (7,23,88). As Berger's (7) research shows, individuals will respond to emotionally significant and personally meaningful stimuli during REM sleep.

The notion that significant external stimuli administered during REM sleep could be integrated with dream content and recovered later during verbal and written reconstructions of dreams is known as the Poetzl effect (23). A major tenet of the Poetzl effect is the claim that complex stimuli may be recorded and maintained in memory below the threshold of conscious awareness for an extended period of time. There is research support for this tenet from studies involving complicated visual stimuli (29,52). Further support for this tenet comes from research findings which demonstrate that repetitive subliminal stimulation (series of tachistoscopic presentations) decreases the awareness threshold as a function of the number of prior subliminal stimulations (23). These findings suggest that the earlier subliminal stimulations are recorded and their effects combined to produce an eventual subliminal response.

There are several methodological difficulties associated with altered states research. One particularly troublesome problem concerns information recovered from the analysis of both dreams and waking imagery and the comparison of the recovered data with preceding subliminal stimuli. In these instances, there are two possible sources of error: (a) the accuracy of assessing the similarity between subliminal stimulus content and the dream or imagery content and (b) the problem of base rate recovery or the extent to which characteristics

of the original subliminal stimuli might be expected to occur by chance in dreams and waking imagery (62). Thus, it is essential that subliminal perception experiments involving dreams and imagery establish stringent standards for comparing subliminal stimulus content with subsequently recovered information.

In general, the research associated with the Poetzl effect indicates that individuals subconsciously analyze the meaning of external stimulation during REM sleep and reflect this information in dream content (25). Several important conclusions relevant to the perceptual-cognitive processing of subliminal information and to related dream research resulted from Dixon's review.

- The validity of dream research is heavily dependent on the scoring of dream material and on the reliability of comparisons between descriptions of dream content and subliminal stimulus material. In this regard, it is necessary to incorporate base rate recovery measures to control for stimulus related dream information that might be expected to occur in dreams and imagery without external stimulation.

- The processes and content of dreams originate in long-term memory. Hence, the construction of dreams reflects the preconscious organizational mechanisms of long-term memory.

- Evolving long-term memory is shaped by need gratification requirements and its organization and processes are oriented accordingly.

- During REM dreams, consciousness suppression effects in filtering and abstracting information are attenuated, resulting in less stringent control of awareness and subconscious release mechanisms.

- It is principally the personal meaning and emotional significance of the subliminal information that determines its retention in subconscious memory. Retrieval of this information depends on available conscious channel capacity, its relevance to ongoing psychological states and/or external situations, and appropriate supraliminal or subliminal priming cues.

It is important to note that the neurophysiological states or conditions commonly associated with phenomena that are endogenously generated also seem to apply to subliminal perception. These states included some degree of disinhibition of the cortical and limbic mechanisms that mediate memory, emotion, and motivation in conjunction with attenuated attentional processes responsible for focused sensory vigilance (60). Knowledge of neurophysiological states that facilitate sensitivity to subthreshold or near-threshold sensitivity would appear to be of special significance and utility in enhancing subliminal perception.

A summary of key research findings and research literature citations pertaining to dreams and imagery is contained in Table 5. For the most part, these findings have been extracted from Dixon's (23,25) extensive analyses. The findings support a linkage between subliminal sensory stimulation and the content of dreams and imagery. In general, this research demonstrates that subliminal stimulation presented during normal waking consciousness influences subsequent dream experiences, spontaneous imagery, imagination tasks, and word association activities. The data base referred to in Table 5 is somewhat dated and not as applicable to the task at hand as other subliminal perception and subconscious processing research under review. However, the dream and imagery data are included here to demonstrate the pervasive potential of subliminal perception as a determinant of human behavior, even endogenously generated behavior.

TABLE 5

Subliminal Perception in Dreams and Imagery

Major Findings
• Subliminal stimulus inputs during normal waking consciousness affected subsequent dream experience.
• Subliminal stimulation influenced subsequent spontaneous imagery.
• Subthreshold stimulus recall was greater through dreams and images than through intentional recall.
• Subthreshold pictorial information surfaced in subsequent imagination tasks.
• Components of subliminal pictorial stimuli were recovered in fantasy images.
• Subliminal pictorial information was represented in free association content.
Key References: 7,8,23,25,29,35,40,47,51,52,69,101, 102,103,104,105,125,126

CRITICAL COMMENTARY

Proponents of subliminal perception have argued that some of the contention and criticism that is associated with subthreshold information acquisition and processing resembles disbelief based on prima facie implausibility (110). Although there is some truth in this statement, a number of negative appraisals warrant further consideration. In this section, some of the prominent criticisms and counterpoints concerning subliminal perception will be examined from two perspectives: theoretical-conceptual and methodological.

Theoretical-Conceptual Critique

There are some who purport that all perception begins with phenomenological experience and progresses by sequential analysis and synthesis. For example, in the area of visual perception, Neisser (86) maintains that the constructive processes through which raw sensory data are converted into finished percepts depend on transient visual memory (icon). He stipulated that the icon which initiates visual cognitive information processing is a conscious, phenomenological experience. Neisser concludes, therefore, that the entire spectrum of subsequent processing must involve conscious awareness.

The notion of an icon or sensory memory system is based on the research finding that individuals continue to acquire information for a short period of time following the termination of a very brief (tachistoscopically presented) external stimulus (4,124). However, as is evident from findings presented in this review, Dixon (23,25) and many others have produced convincing evidence that a conscious iconic process for an associated brief sensory storage period is not necessary for perception. The data show quite the opposite; specifically, that information can be acquired, neurophysiologically processed, and can influence overt behavior, all without conscious awareness of the external stimulation.

Sperling's research with metacontrast or backward masking paradigms also demonstrated that complex visual stimuli could be acquired, processed, and stored even when they are presented for extremely brief durations (4,125,126). Under the conditions of these experiments, letters were read from a display at rates that approached 100 per second, leading Sperling to speculate about the existence of a buffer storage between visual input and verbal coding. Since these early studies, improvements in experimental design and methodology are reflected in a variety of paradigms including binocular rivalry, dichoptic viewing, dichotic listening, pattern masking, and lexical decision tasks. The combined weight of the findings from these various methodological approaches cogently demonstrates that conscious awareness is not necessary for information acquisition, analysis, and processing (23,25,73).

The significance of the subliminal perception findings in relation to Neisser's assertions warrant further discussion. Neisser (86) has

claimed that the constructive processes responsible for converting raw sensory data into complete percepts depend on and follow from the conscious icons. From this perspective, masking is viewed as disrupting the raw representation of visual input (iconic or sensory memory) and, as a consequence, precluding subsequent processing including semantic and features analysis (126,131). It is clear that iconic or sensory memory as conceived by Neisser must be reconsidered because the subliminal perception data clearly show that there is substantial subconscious analysis that occurs prior to the application of pattern masking (25,73).

In essence, Neisser's position reflects those traditional assumptions of identity and perceptual microgenesis discussed earlier. These assumptions emphasize: (a) the correspondence between consciousness and perceptual-cognitive processing and (b) the linear, sequential, and hierarchical nature of information acquisition and processing (73). However, the weight of the data we present in this review renders these assumptions untenable. Subthreshold information, as is evident from the findings, can be acquired and processed subconsciously, as well as in parallel with suprathreshold information.

There was another popular theoretical-conceptual alternative to subliminal perception initially directed at the perceptual vigilance/defense constructs. Some investigators, for example, have attributed the research findings associated with perceptual defense and vigilance to response bias rather than to subliminal perceptual processes (37). The crux of the response bias argument is that individuals are able to consciously recognize embarrassing or threatening stimuli and choose to modify their responses accordingly. The response bias explanation, however, has been strongly refuted by a number of investigators (16,30,36).

Dixon's work is instructive with regard to the response bias hypothesis. His studies, which employed a particularly effective experimental paradigm, unequivocally refuted the response bias hypothesis (21,26,59). Dixon's research design involved measuring threshold sensitivity to one eye while presenting subliminal stimuli to the other eye. This approach offers several advantages that enable experimental effects to be attributed to perceptual rather than response processes.

- The input and output channels are separate; one eye receives the subliminal stimuli and the other measures threshold change.

- Subliminality is attained by manipulating intensity rather than duration. Thus, the individual sees nothing of the subliminal stimulus and the problem of how much the individual sees is averted.

- The dependent variable is visual sensitivity to a spot of illumination (an emotionally neutral, non-meaningful stimuli). Consequently, there is no need to verbalize the emotional or arousing material presented to the other eye, rendering response effects inappropriate and unnecessary.

The research since Dixon's work and Erdelyi's (36) cogent supporting review has been even more convincing. Much of this work has been reviewed in this report. Research into dichoptic viewing, dichotic listening, pattern masking, and lexical decision paradigms has produced highly consistent results. This work largely supports the conclusion that subconscious sensory-perceptual regulation, not response bias, provides the most parsimonious explanation for much of the subliminal perception research findings.

Although the research results overwhelmingly support the conclusion that subliminal perception is truly perceptual in nature and not merely a reflection of stimulus-response conflict, the issue is neutralized if one views subliminal perception from an information prccessing perspective. From this vantage point, the emphasis is not on distinguishing between perceptual processes and response processes, but rather on whether selectivity for awareness occurs relatively early or relatively late in the information processing sequence. Selectivity is a multidetermined process that is pervasive throughout the perceptual-cognitive continuum from initial sensory input to final motor output. Thus, sensory inflow, from an information processing viewpoint, is subjected to multiple transformations and is likely acquired and processed at different levels of awareness.

The last theoretical-conceptual alternative to subliminal perception to be considered is the partial cue hypothesis. Some researchers have suggested that the subliminal perception research findings can be explained by the cumulative effects of partial cues (141). However, the accumulation of partial perceptions that is too fleeting or indistinct to be reported or described would seem to be operationally similar to stimuli processed without awareness (35). Partial awareness appears to result in structurally related responses rather than to the semantically related responses found with truly subthreshold stimuli (5,23,25,42).

Finally, there is a strong theoretical-conceptual rationale for subliminal information acquisition and processing capability concerning the vast disparity between the breadth of the external field of sensory stimulation and the much smaller window of conscious awareness (23,25). In the visual area alone, research has shown that the information acquisition and storage capacity of the visual receptors and visual memory store (icon) are many times greater than the short-term memory system (1,4,124).

Moreover, it is clear from the research reviewed in this report that significant aspects of the stimulus field can be acquired and processed, and can produce subsequent effects, but without achieving phenomenal representation (23,25,73).

Methodological Critique

Most of the remaining contention and criticism referring to subliminal perception center on methodological and procedural matters associated with experimental conditions, experimental design, data analysis, and interpretation of results. Since these problems are easier to adjudicate, they will be merely identified as caveats for the conduct of future scientific research and the interpretation of findings. Table 6 provides some examples of procedural criticisms that have surfaced during the history of subliminal perception research, along with appropriate reference material regarding the critics and specific investigations of concern.

It will be noted that nearly all of the criticisms in Table 6 are directed at earlier studies. The increased sophistication of experimental design and improvement in methodology over the years reached the point where the subliminal perception and subconscious processing research is as methodologically sound as research in other areas of the behavioral sciences. Since the most recent criticism listed in Table 6 concerns the well established pattern masking methodology, some elaboration is in order regarding this particular complaint.

Merikle's (77) criticisms attack a key methodological feature of the backward masking paradigm that has become prevalent in subconscious processing research. His concerns are centered on the adequacy of procedures used to determine the threshold of conscious awareness; the issue of whether the masking technique does, in fact, prevent conscious awareness. In brief, the main thrust of Merikle's argument is that the inability to discriminate a blank stimulus field (no-mask control condition) from a priming stimulus does not necessarily imply an absence of awareness.

TABLE 6

Procedural Criticisms of Subliminal Perception Research

Criticism	Reference
• Failure to employ forced-choice techniques for defining detection thresholds.	• Critic: (61) • Study: (123)
• Preexisting stimulus association strength and serial position effects not taken into account.	• Critic: (61) • Study: (123)
• Absence of a control group and failure to use multiple levels of subliminal stimulation.	• Critic: (45) • Study: (18,120)
• Failure to precisely determine stimulation threshold and level; absence of procedures to ensure accurate experimental equipment calibration.	• Critic: (46) • Study: General criticism
• Variations in lighting and figure-to-background contrast.	• Critic: (46) • Study: General criticism
• Failure to provide exact replication of methodology and experimental conditions.	• Critic: (12) • Study: (61)
• Failure to provide appropriate illumination conditions; failure to use the proper standardized illumination ratio for ambient, blank stimulus field, and for subliminal stimulus field lighting.	• Critic: (108,109, 111) • Study: General criticism

TABLE 6 (Continued)

Procedural Criticism of Subliminal Perception Research

Criticism	Reference
• Subliminal stimulus presented simultaneously with supraliminal stimulus inducing lateral inhibition (stronger stimulus inhibiting weaker stimulus). Recommended methodology involves presentation of subliminal stimulus prior to the supraliminal stimulus or presentation of the subliminal stimulus on a different sensory channel or modality.	• Critic: (23) • Study: (42)
• Compelling adverse cognitive structure, countervailing influences, contrary experimental set, and directing attention away from the locale of subthreshold stimulation.	• Critic: (23) • Study: (6)
• Failure to ensure subliminal stimulus energy and duration falls between the individual's neurophysiological and conscious awareness thresholds.	• Critic: (23) • Study: General criticism
• Failure to consider base rate recovery (extent to which characteristics of the original stimuli might be expected to occur by chance) in experiments involving dreams and waking imagery.	• Critic: (62) • Study: General criticism
• Failure to obtain reliable estimates of stimulus onset asynchrony (SOA) response distributions when conducting pattern masking studies.	• Critic: (5,77) • Study: (41,75)

As examples of the problem, Merikle cites the work of Fowler et al. (41) and McCauley et al. (75). He asserts that the procedures used in these studies to establish the SOA between the mask and preceding priming stimulus were inadequate. Specifically, Merikle claims that an insufficient number of trials were accomplished to ensure the SOAs were truly beyond the level of conscious awareness. Merikle stipulates that a sufficient number of trials must be run to determine if the stimulus-response correlations for each SOA response distribution differ from chance variations. In this view, the SOA level for conscious awareness must be based on a response probability that is greater than zero, but not significantly different from the value expected on the basis of chance variations in performance.

Merikle's concerns are appropriate for reliable estimates of response distributions and for adequate trials at threshold SOAs to establish meaningful response distributions. Nevertheless, the pattern masking and lexical decision research discussed in some detail earlier in this review clearly support the reality of subliminal perception and subconscious information acquisition and processing. Even Merikle acknowledges that the masking studies do demonstrate that the efficacy of the masked priming stimuli remain reasonably constant under different levels of stimulus degradation. Moreover, Balota (5) employed safeguards and controls specifically aimed at Merikle's concerns and still produced findings in support of subconscious information acquisition and analysis.

The bottom line is axiomatic. There has been improvement in experimental design and methodology over time which must continue; as in all science, this is a never ending process. However, one must be impressed with the striking consistency of the findings. The capacity to acquire and subconsciously process subthreshold information appears to have been established.

We will not in this review examine the neurophysiological bases for subliminal capabilities; that will be the subject of a separate review. It is enough for now to say that there is compelling evidence for a neurophysiologic basis for subliminal perception, as well as for a dual information processing system. That review will also provide further support for our often repeated concept of perception and processing of stimuli between conscious awareness and neurophysiologic awareness.

OPERATIONAL RELEVANCE

It appears that subliminal perception and related subconscious information acquisition and processing capabilities are an untapped reservoir of human potential. Full development and utilization of this potentially rich resource offers a promising means to enhance situational awareness and air combat performance, our principal concern in supporting the mission of the Armstrong laboratory.

Subliminal perception and subconscious processing represent latent resources that can be developed to augment perceptual and cognitive skills vital to fighter-attack pilot performance. The initial challenge

is to heighten awareness and sensitivity to the external environment. A corollary challenge is to translate this enhanced awareness and sensitivity into improvements in detection and discrimination acuity, perceptual selectivity, trend apprehension, situation assessment, and decision speed and accuracy.

Early visual detection or "first tally" is crucial to aerial combat performance. Similarly, discrimination acuity is essential for the target recognition and identification tasks important to tactical aircrew performance. Any improvement in sensitivity to relevant cues and the ability to acquire and process cues under internal and external noise is likely to increase detection and discrimination performance.

Success in aerial combat depends on sensory and perceptual capabilities to provide accurate information on performance-critical aspects of the external world. This information must be rapidly integrated to reveal meaningful patterns and a virtually instantaneous assessment of the situation. The ability to quickly recognize meaningful patterns and anticipate situation dynamics under conditions of time urgency and stress is basic to a fighter pilot's survival.

Perceptual selectivity is another important factor in effective air combat performance. Accurate assessment of the external situation from minimum information produces a lead time advantage that can be decisive in tactical air combat. However, it is not easy for an aviator to achieve and maintain an optimum blend of selective or focused attention and broad-band receptivity in the face of bombardment by a complicated mix of performance-critical, ambiguous, and irrelevant stimuli.

It is clear that acquiring a substantial edge in aerial combat is associated with the ability to anticipate situational changes. This capacity seems related to the speed and accuracy with which relevant information can be acquired, integrated, and prioritized. The essence of the anticipatory process is the ability to rapidly and accurately assess current conditions and infer situational trends.

Rapid and accurate situation assessment and trend apprehension give tactical aircrews the lead time needed to cope with a highly dynamic and unforgiving operational environment. Without this capability, aircrews are forced to rely on reactive rather than anticipatory decision processes. As a consequence, initiative is lost and lead time vanishes; the quick, smooth responses required in complex and hazardous situations become increasingly difficult.

The significance of the foregoing is captured in Bruner's (17) observation that accurate perception of the real world with minimal input makes it possible to concentrate one's cognitive resources on foreseeing rather than seeing. Within this context, the research evidence presented in this review demonstrates that individuals can acquire and process subthreshold information and that this information can influence performance. Moreover, information detection, discrimination, and selection processes are central to brain function and operate primarily below the level of conscious awareness (25,87).

Even complex pattern analysis and certain decision processes can be accomplished without conscious awareness.

We conclude that latent subthreshold information acquisition and processing capabilities can be activated and developed to improve information acquisition, discrimination, selection, and evaluation. As a consequence, significant increases in situational awareness and performance might be expected. Keep in mind that in modern air combat even modest improvements in situational awareness and performance can be decisive.

Some examples of aircrew performance benefits that are likely to result from the development of latent subliminal abilities are summarized below.

- Subthreshold information that is relevant to the ongoing task situation can be acquired and integrated with other sensory information to provide a more accurate reflection of actual operational conditions.

- Fewer cues and less redundancy are required for valid decisions because subthreshold and suprathreshold information can be combined to produce the required information in less time.

- Subliminal cues can be used to more efficiently guide the acquisition of performance-critical cues and the filtering of irrelevant information. This increased sensitivity and selectivity permit greater efficiency in extracting critical information from the stimulus field, particularly when the sensory inflow becomes overwhelming in magnitude, ambiguity, irrelevancy (excessive noise), or when there is a pressing demand to acquire subtle cues below or near the threshold level.

- Subliminal marker cues can be utilized to direct attention, enhance critical cues, or prime optimal response programs.

- Subliminal cues and inferential cognitive processes can be combined to aid performance when supraliminal cues are ambiguous or scarce, or when time urgency increases the need for anticipatory judgment and decision making.

- Both subliminal information acquisition and subconscious processing capabilities are virtually cost free (require little or no energy, attentional processes, or conscious perceptual-cognitive resources) and, thus, reduce perceptual and cognitive workload.

- The efficient synthesis of supraliminal and subliminal sensory inflow can be used to heighten awareness and fine tune the economical application of sensory, perceptual, cognitive, and motor resources.

- Easy access to the potent subconscious memory system and the development of a skilled memory structure to support subliminal information acquisition and processing can substantively enhance performance.

- Augmenting the conscious memory system with a subconscious skilled memory component could substantially increase decision speed and accuracy. This improvement would be amplified if the organization of skilled memory content categories represents the actual operational tasks, situations, and environments with high fidelity.

- Utilizing subliminal cues to support earlier situational assessment and trend prediction should decrease decision time without loss of decision validity.

- Early access to subthreshold cues regarding the state of critical causative or driver variables should enhance both trend apprehension and anticipatory decision processes.

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